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Warehousing: Understanding the fundamentals and discovering innovative technological solutions for environmentally and economically improved management

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Abstract

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The purpose of this thesis is to provide readers with little or no knowledge of supply chain management and its integral part, warehousing, a general understanding of the supply chain as a whole, both the functions and types of the warehouse. It explores five different up-to-date warehousing solutions which incorporate latest technologies currently trending in industry.

The technologies introduced in this paper are robotics, radio-frequency identification (RFID), systems involving a light-emitting diode (LED) with motion sensors, automated storage and retrieval systems (AS/RS) and solar power generation. The thesis thus allows readers to understand how fast-developing new high technologies are reshaping the face of modern warehouses.

New technologies are not always easy to incorporate for either individuals or companies. Difficulties arise when adopting a new system or method. In the paper, the reasons for companies not opting for such solutions are studied. Furthermore, with a study of companies considering switching to newer technologies in their warehousing operations, the global outlook for such solutions is discussed.

Keywords
DHL, Zetes, Amazon Robotics, Westfalia, supply chain solutions, warehousing solutions, robotics, radio-frequency identification (RFID), light-emitting diode (LED), motion censors, automated storage and retrieval systems (ASRS), solar-power, Solgen Energy

Table of contents

1 Introduction 1
1.1 Background 1
1.2 Project scope 1
1.3 Project objective 2
1.4 Method of research 2
1.5 International aspect 2
1.6 Anticipated benefits 3
1.7 Key concepts 3
1.8 Demarcation 3
2 Introduction to supply chain management and warehousing 4
2.1 Supply chain management 4
2.2 Warehousing 4
2.3 Need for warehousing 4
2.4 Types of warehouses 5
2.5 Functions of warehouses 6
3 Introduction to green warehousing 8
3.1 Green supply chain management 8
3.2 Green warehousing 8
3.3 The need for green warehousing 8
3.4 Automated Warehouses & Distribution Centers 10
4 Cases of modern technologies across warehousing industry 11
4.1 Light-emitting diode 11
4.1.1 DHL 11
4.1.2 CO2 emissions 12
4.1.3 GoGreen initiative 12
4.1.4 Example of current usage of the system 12
4.1.5 Benefits 12
4.2 Radio-frequency Identification and Voice Picking 13
4.2.1 Zetes Industries 13
4.2.2 ImageID technology 14
4.2.3 Dock Door Control 14
4.2.4 Voice Picking 15
4.2.5 Example of current usage of the system 15
4.2.6 Benefits 15
4.3 Automated robotics 16
4.3.1 Amazon Robotics 16
4.3.2 Example of current usage of the system 17
4.3.3 Benefits 17

4.3.4 Impact of Amazon Robotics 19
4.4 Automated storage and retrieval systems 19
4.4.1 Westfalia Technologies, Inc. 20
4.4.2 Example of current usage of the system 20
4.4.3 Benefits 21
4.5 Solar-powered energy generation 21
4.5.1 Solgen Energy Group 22
4.5.2 Example of current usage of the system 22
4.5.3 Benefits Reduced carbon emission 22
5 Conclusion 24
5.1 Incorporating the technology and its difficulties 24
5.2 Global outlook 25
5.3 Own learnings 27
5.4 Further development 27
6 References 28
Appendices 33

1 Introduction

Implementation of new technologies is introduced to adapt to fast-changing markets and to achieve sustainability. It is streamlining the supply chain through computerized systems and lean production in order to sustain end-to-end visibility.

1.1 Background

My research idea of studying different warehousing solutions that focuses on incorporating new technologies was formed during my study of Supply Chain Management (SCM). I have been taking part in different supply chain courses and warehousing management became my primary interest. As a result of multiple group projects and individual studies related to warehousing solutions, I have gradually started to gain more personal interest in the subject of how advanced technologies can be embraced and applied to warehouses for the aim of increasing the efficiency in both cost and environmental aspects.

1.2 Project scope

SCM is now benefiting more than ever from advanced technologies. As a student in the field of efficient warehousing management, through new technologies I have identified five solutions. Each model uses its own specification of technologies but their aim is identical; to reach cost savings and environmental protection in warehousing operation. DHL's light-emitting diode (LED) solution works as installing more efficient LED lamps with motion censors so both maintenance and running costs of warehouses can be reduced. Zetes' Door Lock system is installed with bars around the gate of the warehouses with censors that identifies the parcels and tracks them so the goods are moved with error-free condition. The Voice Picking system works as the loading workers use microphones to communicate with the host system in order to receive and confirm picking instructions in real-time. The Amazon Robotics' solution offers robots and the main computer system, so as the computer receives the orders, the signals are sent to robots to automatically pick up the product and deliver it to the bay or truck, all without man-power, thus reducing the labors and, in long term, saving costs and protecting environmental damage otherwise incurred with operating trolleys with human operators. Wesfalia's AS/RS solution allows warehouse to operate with automatic parcel storage and retrieval system so that large parcels can be stored and retrieved upon command using mechanical devices and a controlling computer system. Solgen Energy Group's Warehouse Solar System offers solar panels to be installed on either rooftops or near the location of the warehouse with a monitoring computer system. The solution's aim is to harvest solar energy during daytime to generate electricity, which is used in operating and maintaining the warehouse. Therefore, the warehouse converts self-efficient in power generation, which trims down operating cost.

1.3 Project objective

The aim of this paper is to provide companies or general readers with the understanding of warehouse operations inside the supply chain in terms of its need and type, and five warehousing solutions based on using modern and efficient technologies. Solutions researched are:

A. DHL's LED lights with motion censors
B. Zetes Industries' Dock Door Control and Voice Picking
C. Amazon Robotics' robots
D. Westfalia's AS/RS
E. Solgen Energy Group's Warehouse Solar System

Companies may have inefficiency in warehousing management and maintenance. Above-mentioned solutions may provide new ways to tackle warehousing and increase the efficiency of warehousing management, which benefits from cost saving and environmental protection.

1.4 Method of research

The primary method for conducting this research was based on secondary research. The breadth of data available online provided wealth of information for conducting this study. There is a gamut of data available for each business, enterprise and industry and several objectives can be fulfilled by making use of such information. (Cleverism, 2016) As the above-mentioned five solutions and their information on costs and effects can be found from official websites and accounts from real users and companies, the desktop research was most suitable for this paper's development. Because the research was focused on current trends of the industry solutions the need for up-to-date source was presented. The secondary research paved the way for gathering newest information. Secondary analysis carried out by an independent research could, among other things, lend new strength to the body of fundamental social knowledge. (Glaser. 1963) As the exploration begun and the thesis developed, I have gained new insight into warehousing industry that was not anticipated at an original planning phase.

1.5 International aspect

The benefits of innovative warehousing solutions from the perspective of companies in need of reducing the operational costs and environmental damages can be widely incorporated across global businesses and their related activities.

1.6 Anticipated benefits

The paper provides the general readers with the fundamentals of warehousing operation. In addition, expected benefits to the business practitioners are, upon incorporating the technology, cost savings and environmental protection on their warehousing operations.

1.7 Key concepts

Supply chain management is based on the fundamental idea that every product that reaches its end customer has cumulative efforts of multiple organizations. These organizations are collectively referred to as the supply chain. (Handfield. 2011) Green supply chain management (GSCM) incorporates the ecological factors into the supply chain system in order to address the environmental concern and increase efficiency and productivity. Patrick Penfield from Whiteman School of Management describes the GSCM as “the process of using environmentally friendly inputs and converting these inputs into outputs that can be reclaimed and re-used at the end of their lifecycle thus, creating a sustainable supply chain.” (Cognizant. 2008) An easy and simple way to describe a warehouse is: ‘A warehouse is a planned space for the storage and handling of goods and material.’ (Fritz Institute). Warehousing is part of the company’s SCM. With today’s technological advances, companies with warehousing operations have been able to benefit from such technologies for increasing its efficiency of the system. Implementation of new technologies to adapt to fast-changing markets and to achieve sustainability or streamlining the supply chain through a computerized system and lean production in order to sustain end-to-end visibility. Thus the green warehousing concept has been created.

1.8 Demarcation

The five solutions were chosen after researching several major companies operating in the industries of logistics, retail and supply chain solutions such as Deutsche Post, Deutsche Bahn, Amazon.com, TNT Express and United Parcel Service. The research was primarily done using the internet to gather information such as annual reports, product lists and testimonials of the clients. After amassing different types of solutions, I have selected five technologies with criteria that the solutions must:

a. Generate cost-saving effect,
b. Reduce environmental footprints,
c. Differ fundamentally, as in nature of the technology, from one another.

2 Introduction to supply chain management and warehousing

Many companies around the world are starting to discover the competitive advantage gained by SCM.

2.1 Supply chain management

SCM comprises business operations such as manufacturing, purchasing, transportation and physical distribution. Then it incorporates all chains into a management and integrates them into a seamless process that yields more efficiency. Third-party partners such as suppliers or carriers are also merged into the supply chains. Within the organization, the supply chain activities are classified as warehousing, inventory management or inbound and outbound transportation. (Zigiaris. 2000)

2.2 Warehousing

Our daily lives are filled with different types of goods purchased from different producers and sellers. Consumers may buy large quantities of certain goods at once for many reasons such as preventing shortage of goods in near future or buying in bulk at relatively cheaper price. Similarly, businesses store their goods for different reasons.

2.3 Need for warehousing

Warehousing is an integral part of supply chain and depending on the nature of the business model, commodity or product the need for storing goods may vary. There are six different needs for warehousing. (NIOS, 2015)

1. **Seasonal production**

Certain types of commodities such as agricultural goods are harvested in certain seasons, but their consumption may continue throughout the year. Therefore, a large amount of these goods are produced and they are stored in order to be supplied when the demand is met.

2. **Seasonal demand**

Products such as umbrellas or winter boots may have fluctuating demand throughout the year depending on which season they are sold. So there is a need to store these goods in order to make them available at given time.

3. **Large/scale production**

Produced goods are manufactured in large scale in order to meet the current as well as future demand. Also, manufacturers produce goods in large quantity because it is more economical.

4. **Fast supply**

Generally, goods are consumed throughout the country, therefore it is important to place the finished goods near the site of consumption in order to expedite the process of shipment to final consumer.

5. **Continuous production**

When the production is done continuously throughout the year, there is a need to store raw materials in order to maintain the production at a steady rate.

6. **Price stabilization**

In order to maintain the stability of price of the products in the market, the stock of goods must be kept at sufficient level. Scarcity in the supply of products may result in increased price of the goods, in same token, excess production may lead to decrease in the price of goods.

2.4 Types of warehouses

Warehouses share a single idea: storing goods. However, depending on who operates the warehouse it may differ. Warehouses can be classified into five different types including: private warehouses, public warehouses, government warehouses, bonded warehouses and co/operative warehouses. (NIOS, 2015)

1. **Private warehouses**

Private warehouses are owned and administrated by the private manufacturers. Theses warehouses are designed specifically to store the products with consideration of their nature such as adequate temperature level or lighting.

2. **Public warehouses**

The government may regulate the operations of these warehouses. Manufacturers, exporters, importers, government agencies or wholesalers mostly use such warehouses. An individual, a firm or company can own one too.

3. Government warehouses

These warehouses are owned, ran, and controlled by the government. They are used for storing government properties.

4. Bonded warehouses

These warehouses are maintained and controlled by both the government and private entities. Private entities are required to acquire a license from the government to operate such warehouses. Generally, harbor and dock authorities own these warehouses in order to store imported goods that need to be paid duty taxes.

5. Co-operative warehouses

These warehouses are owned and managed by co-operative societies. These warehouses are designed to be economical so that the members of the society can have access to it.

2.5 Functions of warehouses

Warehousing operation is, as logistics and SCM receive more attention from the top management due to realization of more added-value after streamlining such operations, becoming more important to the businesses. Warehousing is generally, in large, integrated and dependent on other supply chain activities. Key fundamentals of warehousing can be described with 7 operating activities. (2002, Frazelle)

1. Reception

Warehouses receive goods with assurance that the quality and quantity of such products are as ordered.

2. Packaging

When the goods are received in bulk from a vendor and subsequently packaged individually, or in bundle with other products or parts, the prepackaging is performed at the site.

3. Storing

Storing, or stockpiling, is the activity of placing merchandise in storage often sorted by its types to expedite the handling.

4. **Order picking**

When the demand is created by the sales order and issued by the customer, warehouses remove ordered items from its storage to be placed on shipment. This activity is one of most critical functions and how a lot of warehouse designs are based.

5. **Sortation and/or collection**

When more than one single item is placed on order, sortation of batch picks, also known as multi-order picking illustrated by joining goods from multiple orders into one pick direction, individual orders and accumulation of distributed picks into orders are done. Sortation by batch picking increases the efficiency by maximizing pick quantities and minimizing operator-walking distances.

6. **Unitizing and shipping**

When the products are sorted, orders are checked for completeness. The goods are loaded to the carrier, in many cases trucks, which usually have different destinations.

3 Introduction to green warehousing

With technological developments and increased social awareness on preservation of nature, warehousing industry has come to embrace green operations.

3.1 Green supply chain management

The economic growth seen in recent decades, coupled with increased consumption in both materials and energy, saw the rise of environmental concern for climate pollution and resource depletion. Thus, governments and policy makers around the globe have long been pushing the new laws and directives regulating the environmental scopes of business practices. At the same time, business entities began to recognize the potential cost benefits derived from adapting to advanced technologies. It also saw increased brand image and customer royalty through corporate social responsibility. (IJMVSC, 2015) As a result, GSCM has risen as a new systematic management, which focuses on improving the overall supply chain activities with environmental concern in mind. Many leading companies have accepted it and the number of companies with interest is growing. GSCM is defined to be ranging from green purchasing to integrated supply chains including supplier, manufacturer, customer and reverse logistics. (IJMVSC, 2015)

3.2 Green warehousing

Green warehousing is about incorporating environmentally conscious elements into the warehousing process and functions in order to optimize the flow of goods while reducing the waste while maintaining the optimum service. Generally, when moving towards environmentally friendly warehousing, approaches will facilitate for businesses with managing costs and eliminating wastefulness through space utilization, maintaining efficiency, integrating intelligent electrical systems among many other solutions.

3.3 The need for green warehousing

According to US power organization Madison Gas and Electric, energy bills from a warehouse's operating budget can account for as much as 15.0 percent. (Madison Gas and Electric Company. 2016) Also a report from Touchstone Energy claims it can reach as high as 10.0 percent of the total revenue. In non-refrigerated warehouses, lighting takes the largest portion of the total energy consumption that accounts up to 60.0 percent. (Figure 1)

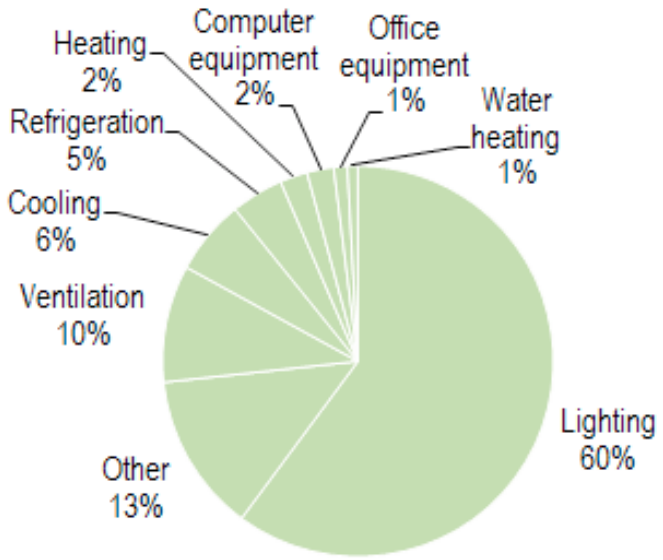


Figure 1. Energy Consumption by End Use in Warehouses. (Madison Gas and Electric Company. 2016)

Another study states that 12.0 percent is made up of heating which is commonly generated by gas or oil. (Warehousing & Logistics International. 2016) The more accurate allocation and its prices vary from different regions however it is clear lighting and heating are generally the main targets when company sets off to build more green and energy efficient warehouses. In 2008, technology consultancy firm Bearing Point along with Supply Chain Standards conducted a “Global Green Supply Chain” survey among chief firms and companies with less than 100 million US dollars in revenue.

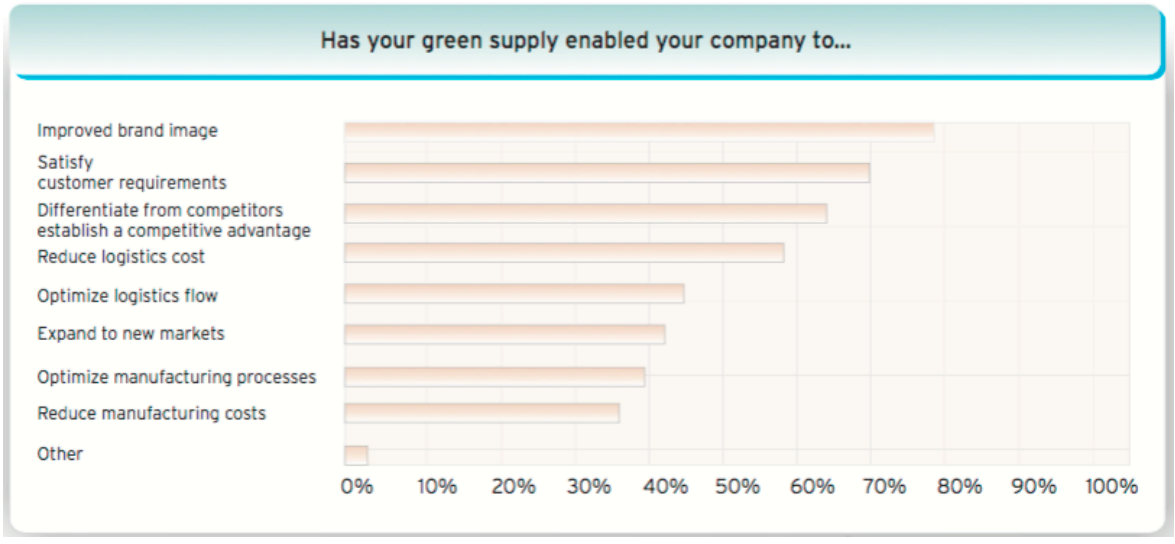


Figure 2. Green for Go Survey (Bearing Point and Supply Chain Standard on Global Green Supply Chain, 2008)

The survey included more than 600 senior managers. It revealed that managers identified green supply chain with improved brand image, satisfied customer requirements, increased competitive advantage, reduced logistics cost and many more. (Figure. 2)

3.4 Automated Warehouses & Distribution Centers

The automated warehouse is an integral part of green warehousing because it often reduces the carbon footprints and operational costs. Carefully planned automation system leaves little or no wastes. An automated warehouse is a commercial building in which functions such as receiving, storing and distributing goods as well as packaging; maintenance and other pre-outbound tasks are completed by an automated system. All types of goods maintained in a warehouse or distribution center are carried by robotic systems with the assistance of conveyors and overhead pulley systems. Computer systems are located in strategic locations to facilitate the moving of these goods from bulk storage area to the next activity areas of the warehouse. Automation process often yields additional reduction in operating cost and environmental footprints as less human labors are required.

4 Cases of modern technologies across warehousing industry

Numerous companies provide supply chain solutions with advanced technologies to improve its customer business' supply chain operations. Five technologies and solutions providers are chosen based on the preliminary research. The brief overview of technologies and its benefits are described.

4.1 Light-emitting diode

LEDs, or light-emitting diodes, are two-lead semiconductor devices that create light that is visible to the human eye when an electric current passes through them. (EnergyStar, 2016) A diode is composed of a layer of electron material with another layer of electron deficient material, which forms a junction. Power is then applied to the junction, which in turn excites the electrons in order for photon emission, the light is then formed. LED's are more efficient than the conventional light bulbs for several reasons. LED's emit brighter light than incandescent lamps because of uniform light dispersion. It is also more energy efficient producing up to 90 percent light output compared with conventional lamps using up to 90 percent of energy generating heat. Because LED's produce colored light with no need for additional filter for coloring, the extra energy is saved. (University of Notre Dame, 2016)

4.1.1 DHL

Deutsche Post AG, operating under the name of Deutsche Post DHL, or simply DHL, is a Bonn-based world's largest carrier company by the amount of handling and revenues. It employs almost 500,000 workers around the world in more than 220 countries. Its division of main operations include Mail, Express, Forwarding/freight and Supply Chain/Corporate Information Solutions. (Deutsche Post DHL. 2013a) As the social responsibility and corporate image observed by the public is becoming ever more crucial throughout the globe, DHL's green warehousing is gaining more momentum as a project every year. However, DHL's move towards green solutions is not only a result of increased public awareness but also the company's own initiative and need to improve the efficiency of the operations in order to cut costs. The program not only offers its innovative solutions to DHL's operation but also to other firms and companies with matching demand.

4.1.2 CO2 emissions

CO2 emissions are the single largest environmental damage created by DHL every year. A total of around 5.6 million tonnes of CO2 was produced by DHL in 2013 alone. Of which 64%, largest slice, were from air transports, 22% from road transports, and 14% from real estates. (Deutsche Post DHL. 2013b) This was an increase of 3.7% from previous year (5.4 million tonnes of CO2) due to meeting with new demands throughout the world. Operations of warehouses, included in the 'real estates', accounts for nearly one-fifth of the whole CO2 emissions emitted by DHL's operations.

4.1.3 GoGreen initiative

Inside the DHL's green warehousing initiative there is a core project called "GoGreen Program". Its objective is to slash carbon dioxide spawned from and the cost of operating the warehouses. The program has set a goal to reduce 30.0% of operational carbon dioxide by 2020. (Deutsche Post DHL. 2013c) Through new developments, bringing more efficiency in terms of environmental protection and cost to its supply chains is the aim of the program in a nutshell.

4.1.4 Example of current usage of the system

DHL completed the assembly of the first carbon neutral warehouse near Wakefield West Yorkshire with the help of DHL's in-house carbon consultancy "DHL Neutral Services". Designed to be used as a main distribution center of UK communication company O2, the finished site of the warehouse is 604 m2. Inside the warehouse, installation of LED lighting system with motion censors to detect movement inside the warehouse is installed for reducing energy consumption. The censors around the warehouse shut the lights off automatically if no movement is detected. (Eft, 2008)

4.1.5 Benefits

Carbon Deduction

98.0 percent of warehouse's carbon emission is completely eliminated, through LED lighting with motion censors. (Eft, 2008)

Cost saving

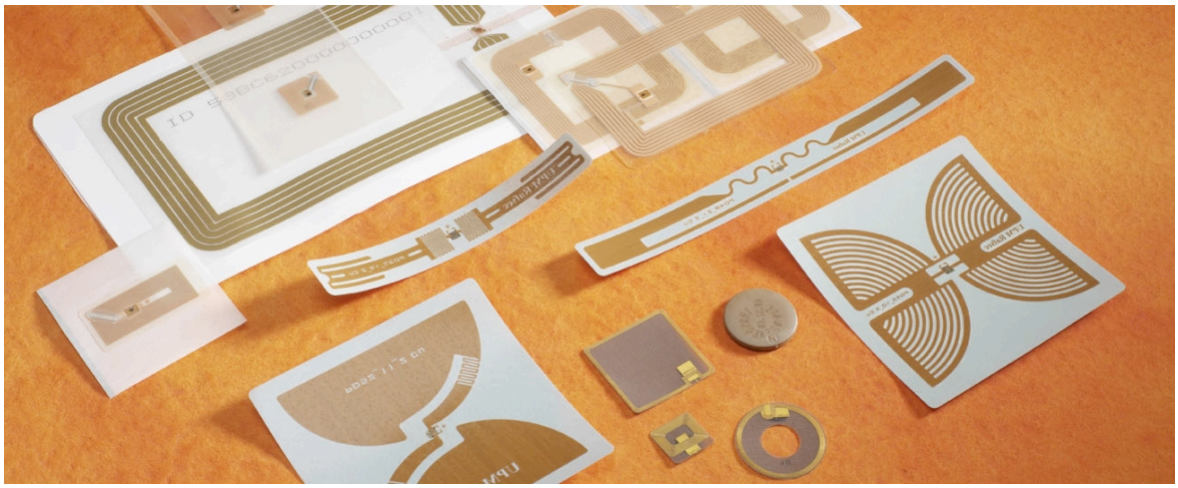
According to Huw Phillips, a Program Director at DHL Real Estate, the cost of installing the program is, on 2013, just short of €500,000 and, in return, is yielding a financial savings of more than €200,000 annually. (Eft, 2008)

Continual improvement

After the installation, DHL gathers data on a regular-basis and analyze them for continual improvement of the program in the future.

4.2 Radio-frequency Identification and Voice Picking

RFID stands for Radio-frequency Identification. The acronym refers to a tiny system that consists of a small chip and an antenna. This technology functions with the same purpose as the barcode or magnetic strip on the back of a credit or check card. (Technovelgy, 2016)



Picture 1. RFID Chips and Antenna. (Zetes. 2016)

Tags are attached to items to be traced. Tags are made from a chip, also called integrated circuit, and it contains data such as product or storage information. An RFID reader with an antenna will send signal and communicate with tags to receive information. (Impinj, 2002)

4.2.1 Zetes Industries

Founded in 1984, Zetes Industries is a technology company currently headquartered in Brussels that has set an objective to provide supply chain solutions around the world. Within the wide range of solutions, ZetesMedea Dock Door Control system has many benefits for increasing productivity and accuracy of the material handling inside the ware-house. Operations of warehousing pose the threat of incorrect deliveries due to human error in the final packaging process. ZetesMedea Dock Door Control insures 100 percent accuracy of the pallets at the final truck loading procedure, which in return guarantees the safety and efficiency of the items delivered. (Zetes. 2015)

4.2.2 ImageID technology

Developed by the Zetes Industries, ImageID technology is a system consisting of computers and cameras, which detect the barcodes on the pallets. It has three main features:

- Great detection area
- Depth, highly penetrable, of detection
- In-motion detection

The camera is able to scan the barcode/label in any given position of the pallet, thanks to the use of RFID. The direction or the distance of the barcodes from the camera does not impede the identification of the pallet.

4.2.3 Dock Door Control

Industrialized by the Zetes Industries benefiting from ImageID technology, a camera, at the passage or the door, between the warehouse and truck, captures the photographs of every crate/roll carrier/pallet that is loaded on to the truck. It then instantaneously detects and analyses the barcode or label on the crate and gives a go/stop sign for the loading operator.

Illustration 1. Dock Door Control Procedure. (ZetesMedea. 2015)

The operator, during the process of loading/unloading the pallets to/from warehouse, can pass through the door at any direction. The operator is able to pass the gate up to 20km/h. (ZetesMedea. 2012a) Images are collected in a cloud-based system for later use, for example, a possible legal issue regarding false shipment. In certain situations, for example, when there is no direct display of barcode is present, RFID technology is used for the verification of the pallet. RFID technology utilizes wireless electromagnetic fields to transfer

data for classifying and tracking each pallet without the need for barcode to be scanned manually by operators.

4.2.4 Voice Picking

Voice Picking is another warehousing solution developed by Zetes which uses voice recognition technology that lets operators in the warehouse communicate with the host system, using voice terminal and headset, to receive and authorize picking instructions in real-time. It returns 20 percent productivity and up to 99,9 percent accuracy level. (ZetesMedea. 2015)

4.2.5 Example of current usage of the system

Asco is a company specialized in manufacturing components for the aeronautics industry. It develops, produces and processes the high precision steel and titanium parts. The company was in need for improving the process of manufacturing and machining so that maintenance cycles would be optimized and audit requests will be responded to quickly. The Zetes Industries offered the RFID tags solution which is beneficial for identifying tags using unique identification with no errors and also boasting high resistance to emitting of metal flings and long-lasting exposure to cutting liquid that happens around the manufacturing area. RFID readers were installed at the entrances and exits of both manufacturing and warehousing facilities. Asco now benefits from the new system with completely automated tool management and receives and collects information in real-time. The new identification technique has no footprint on the ground because of the automated system. (Zetes, 2012) All the data is now stored in database so company can respond quickly to audit demands.

4.2.6 Benefits

Increased accuracy

Dock Door Control-mounted gate checks the barcode on every pallet going through the gate and grants access to the operator of the forklift based on the collected barcode information. It causes decline in returns and claims caused by incorrect deliveries.

Environmental awareness

Incorrect deliveries that may cause trucks returning or sending another package ultimately create additional environmental footprints that could be prevented by installing the system because it insures 100 percent proof of accurate deliveries. (ZetesMedea, 2012b)

Improved productivity

With the solution, there is no need for one operator to work on one specific loading/unloading of materials, however different operators can work simultaneously on pallets. RFID captures the barcodes even when the pallets are in motion so it improves the overall processing time of the pallets. Additionally, no personnel are required to be trained for the operations thus the system can be installed and be used straightaway.

Increased traceability

Every pallet passing through the gate has pictures taken by the camera and stored in cloud-based storage system. This action improves the traceability of the pallet when pallet is lost or damaged in other point during the process of supply chain.

4.3 Automated robotics

Conventionally, goods are moved from one area to another by human or machinery operated by human workforce. However, a robotic system operates inside the warehouse using computerized barcode stickers, which is used for guidance for location, positioned on the floor of the facility. There are drive units, which are equipped with sensors to avoid collision. After successfully reaching the correct station, the robots "positions itself beneath a pod and lifts it from the ground to carry it to a work station" (Kiva systems. 2015) At the station, with the help of a laser pointer, picking lights, computer monitor and barcode scanner, a human operator selects the required items for the robots to pick. Multiple orders are normally picked by multiple workers concurrently." (Technology Advice. 2013)

4.3.1 Amazon Robotics

Amazon Robotics, formerly a Kiva Systems before acquired by Amazon, is located in Woburn, Massachusetts. Mike Mountz the CEO, in 2003, created the company. Mike wished to develop a system that would "improve the pick, pack and ship process through a goods-to-man system based on one basic principal – it need be able to deliver any item to any operator at any time." (Kiva systems. 2015) Kiva Systems was created on following 4 fundamental components:

- Merchandises should systematize themselves
- One equipment should handle all products
- A material handling solution should be scalable
- Orders should be filled upon customer demands

(Kiva Systems 2014)

In March 2012, Amazon wholly acquired the company and its system for 775 million US dollars. (Technology Advice. 2013)

4.3.2 Example of current usage of the system

Currently, the system is being used by numerous companies in the United States. Companies such The Gap, Walgreens, Staples, Office Depot, Crate & Barrel, and Saks 5th Avenue are few examples. The Gap Inc. Direct is one of the world's leading specialty retailers of clothing for women, men and children.

Picture 2. Amazon Robotics in Action (CNN Money. 2014)

Kiva System announced on March 2010 that the Gap Inc. Direct would be implementing Kiva system at its fulfilment center in Columbus, Ohio. The company operates under a variety of a brands and names such as the Gap, Banana Republic, Old Navy, Piperlime and Athleta. The company tested the system throughout the summer of 2009, which proved to be beneficial and the trial has led to a decision to order an additional system for their Piperlime brand facility. (Kiva systems. 2015) In the US, Amazon now boasts a workforce of 15,000 Kiva robots deployed across 10 of its 50 domestic fulfillment centers." (Wired. 2014)

4.3.3 Benefits

Reduced carbon emission

Substantial reduction in the level of carbon is achieved through the usage of machine and robotics which can function in the facility without any lighting that was needed when hu-

man labors was required. Crate & Barrel, which implemented the solution in 2010, affirmed “Kiva’s mobile robotic approach is not only the most cost-effective way to automate pick, pack and ship operations, but also the greenest. The robots themselves are energy efficient, plus the entire robot zone can be operated with almost no lighting.” (Business-Wire. 2010)

Reduced cost of electricity and heating

With the Amazon Robotics’ solution, companies would reduce its electricity consumption noticeably. Each robot is operated using a battery which has a life span of 8 hours before recharging is required, which takes mere 5 minutes. The robotics and the rest of the system automatically shut off when not in use. This would allow companies to reach high efficiency by not using as much lighting and heating before the installation of the system. (Amazon Robotics, 2016)

Improved quality of life

The collaboration of men and machines has, in many cases, resulted in fatale consequences. With the Kiva solution, interaction is reduced as the robots do most of the physical work. For human workers, physical acts such as bending, stretching, reaching or travel fatigue are decreased significantly. The level of noise is also decreased vastly. The traditional conveyor is noisy and demands operators to wear protective ear gear to minimize hearing loss.

Increased productivity

Travel time associated with restocking and order picking would be reduced. Amazon robotics states it would slash the activity time by 5-6 times. Generally, the traditional method of manual pick-up is averaged at 100 order lines per hour, and 180 in very efficient fulfillment centers. However, with the Amazon robotics, warehouses would be able to increase productivity to 600 order lines per hour. Staples Inc., the world’s largest office supply chain stores and one of the first adopters of the system, reported pick up rates of 600-700 order lines per hour compared to their pick-to-belt system which had a rate of 200-400 lines per hour. (Kiva systems. 2015)

Increased accuracy

Although the system still requires human personnel to complete the task of order picking, the level of human interaction is greatly reduced and therefore the occurrence of human error is minimal. Most non-automated warehouse facilities report that the highest amount of mistakes are made during the pick-up process, this sophisticated system allows for more accurate outcome.

Increased flexibility

The system works with a variety of “product types, product velocities, order prioritization, and other operational realities”. (Kiva systems. 2015) The system’s flexibility is one of many benefits retailers considered when adapting to the system.

4.3.4 Impact of Amazon Robotics

Companies such as Staples, Walgreens, the Gap Inc. and Quiet logistics, which have invested in the Amazon robotics solution, reported improvements in productivity and reduction in carbon footprint. (Kiva systems. 2015) Amazon, which acquired the company, reported more than 15,000 robots have been deployed in 10 of its largest warehouses across the country just in time for the 2014 winter holiday season. (Kiva systems. 2015) Companies would achieve a more sustainable operation by implementing the system into their warehouses and distribution centers. Companies would be able to improve the efficiency of warehousing processing, the quality of life for their employees, reduce carbon footprints, and human errors. The solution would result in multiple cost savings for the company in the long run in addition to meeting the demands of its customers and supporting an ecological balance in the environment.

4.4 Automated storage and retrieval systems

An automated storage and retrieval systems (AS/RS) is a combination of mechanical equipment and controls system, which uses automation technique in order to store and retrieve pallets or other stored items in warehouse upon operator’s command. The system first appeared on the material handling scene as early as 1960s, however with the introduction of computer and electric components, the system has evolved since to a more sophisticated method. (Modern Material Handling, 2012) The system is computer-controlled and is able to automatically deposit and/or retrieve loads to/from defined storage locations. The system contains computerized controls, horizontal and vertical carousels, a vertical lift module, tracks, and an aisle for storage. (MHD, 2016)

Picture 3. AS/RS Storage System in Motion. (Direct Industry. 2016)

Upon receiving an order from a customer or at the operator's manual command, the computer locates the position of the storage item and the retrieving machine follows the guide line, using a pre-installed network of tracks and cable, to grab the item and bring it to the packing area. The system is highly beneficial for customers with warehouse accommodating heavyweight loads.

4.4.1 Westfalia Technologies, Inc.

Westfalia, headquartered in York, Pennsylvania, US, develops and provides warehousing solutions to its customers. Since 1992, its logistic solutions for plants, warehouses, and distribution centers were started. Today, the company employs approximately 300 staff around the globe providing services.

4.4.2 Example of current usage of the system

Cooperative/Organic Valley Family of Farms (CROPP) is America's largest cooperation of organic farmers. The organization was growing fast and the need to accommodate larger storage capacity and efficient management was met by the AS/RS solution. As a result, Westfalia Technologies installed, in 2007, an AS/RS for CROPP's new 80,000 square feet distribution center in Cashton, Wisconsin. The result was a 40 percent deduction of the

space of the conventional warehouse that was originally planned by the CROPP. In addition, the new warehouse benefited from 40 percent reduction in energy costs of which 30 percent was due to highly automated process of the AS/RS solution alone. (Westfalia, 2016) The high-density warehouse now means less land is utilized therefore less environmental impact is occurred. In addition, safety of the employee is now increased because less human labor is required.

4.4.3 Benefits

Increased storage space

By installing the ASRS with highly customized set-up, the warehouse can achieve up to 70 percent more pallet storage in existing facility. (Westfalia, 2016)

Minimized footprint

The system is able to decrease overall building footprints up to 50 percent compared with conventional warehouses. (Westfalia, 2016)

Reduced energy cost

With automation and less manual material handling, the set-up reduces the running cost by 40 percent. (Westfalia, 2016)

Decreased labor and product damage cost

Automation process requires less human labor thus it reduces the cost of both labor and product damage that may have followed by human error.

Increased inventory accuracy

Sophisticated computer systems ensure accurate delivery of the item to the operator hence decreasing the error and increasing the customer satisfaction.

4.5 Solar-powered energy generation

Generating energy from solar power is not a new idea in modern energy industry. Its history extends to the 7th century B.C. where mankind used glass and mirrors to light fires. (U.S. Department of Energy, 2015) Photons, particles of sunlight, hit the solar panels. The panel then converts photons into electrons of direct current, also called “DC”, electricity. DC is transferred from the panel into the inverter, which converts the current into alternating current, or “AC”, power. (CNU & CPUC. 2007) AC is what powers most of everyday electrical devices such as computers, refrigerators, and lightbulbs. Today, solar-powered energy generation is placed into everything from individual households’ rooftops to large

warehouses and other buildings. Modern-day's sophisticated solar technology is enabling warehouses to be more efficient in terms of cost saving and environmental protection.

4.5.1 Solgen Energy Group

Based in Sydney, Australia, Solgen Energy Group provides solar powered products and services, which include designing, installing and maintaining the system. Its clients within Australia range from commercial, industrial, and government to residential. The company is a member of the Clean Energy Council of Australia, which represent hundreds of businesses in clean energy such as solar, wind, hydro or bioenergy. (Clean Energy Council, 2014) Its products are certified with International Organization for Standardization, often known as ISO, and its quality management ISO9001 and environmental management ISO14001 are to ensure the products meet demands of quality and environmental protection.

4.5.2 Example of current usage of the system

In 2013, Solgen Energy designed and installed a Warehouse Solar System at the warehousing facilities of Clifford Hallam Healthcare (CH2) located in Eastern Creek, Western Sydney.

4.5.3 Benefits Reduced carbon emission

By installing the Warehouse Solar System, the new CH2 warehouse saves over 128.2 tons of emissions annually. (Solgen Energy, 2013)

Energy from renewable sources

By installing the Warehouse Solar System, the new CH2 warehouse saves over 128.2 tons of emissions annually. (Solgen Energy, 2013)

Positive action on climate change

The installation of the solar panels to the warehouse demonstrates positive action towards climate change within community.

Reduced need for investment in conventional coal-fired power stations

With much of power now generated by solar energy, the demand for the traditional coal power is reduced.

Safe monitoring

Computer system is designed to maintain and monitor the solar power system. It collects data for maintenance and repair.

5 Conclusion

As technologies grow faster than ever, the warehousing operations have been benefitting with the use of modern skills and tools. Five different warehousing solutions have been explored with each model offering distinctively different technologies to assist in making customer company more efficient and environmentally friendly in warehousing operation.

5.1 Incorporating the technology and its difficulties

Incorporating some of these newly-introduced technology solutions will require ample amount of financial funding as these technologies have yet to bring a full “trickle down” effect across the supply chain scenes of all industries mainly due to the high set-up cost and sometimes the lack of knowledge. When the new technologies are introduced, as often the case, the price of acquiring them is considerably high. For example, in the case of Amazon Robotics, Amazon.com procured Kiva Systems in 2012 after paying 775 million US dollars in cash. This was Amazon’s most substantial acquisition in company history. (Boston Globe Media Partners, 2012) According to the survey conducted in 2007 by the Aberdeen Group, an American technology and services company which conducts research and survey on business practitioners, 42 percent of respondents replied the chief reason for not investing in warehouse automation was due to the high upfront cost of installation. (Figure. 3)

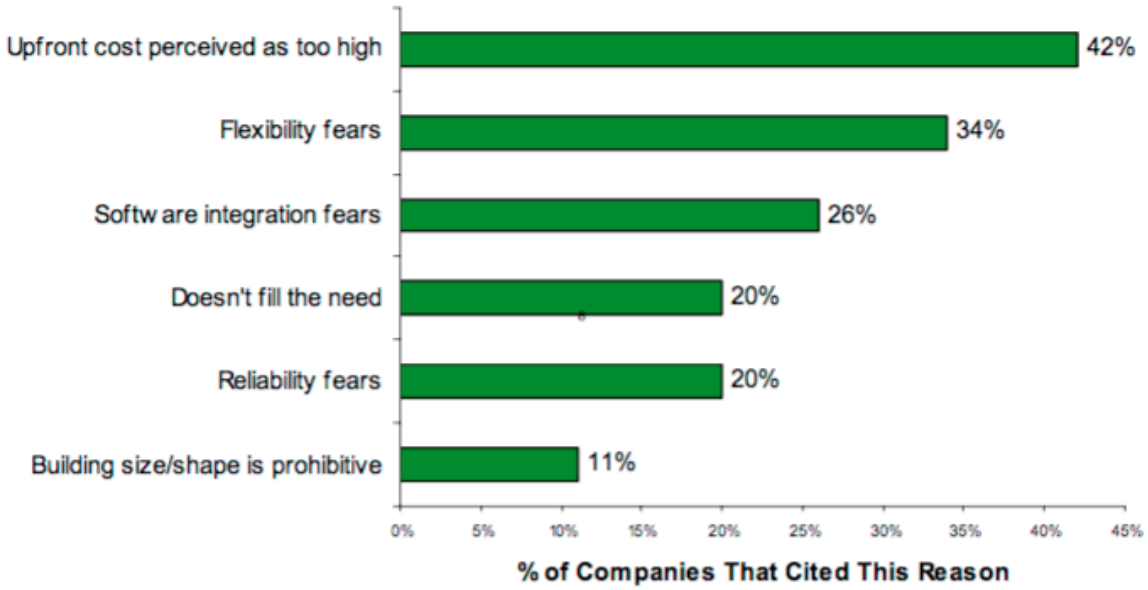


Figure 3. Companies’ Top Reason for Not Investing in Warehouse Automation (Aberdeen Group, 2007)

Only 20 percent answered the need was not present. In addition, 41 percent, the majority, of companies were using traditional bar-code scanning technology, which requires significant amount of human labors. Only 10 percent were operating on AS/RS, 9 percent on voice-picking system and 4 percent on RFID tagging. (Aberdeen Group, 2007)

5.2 Global outlook

As LED market volume expanded from 9 billion euros in 2011 to 37 billion euros in 2016 with the outlook forecasting 64 billion euros by 2020, that is 61 percent of global lighting market, the price of semiconductors and LED lamps is expected to continue decrease rapidly. (Statista, 2016)

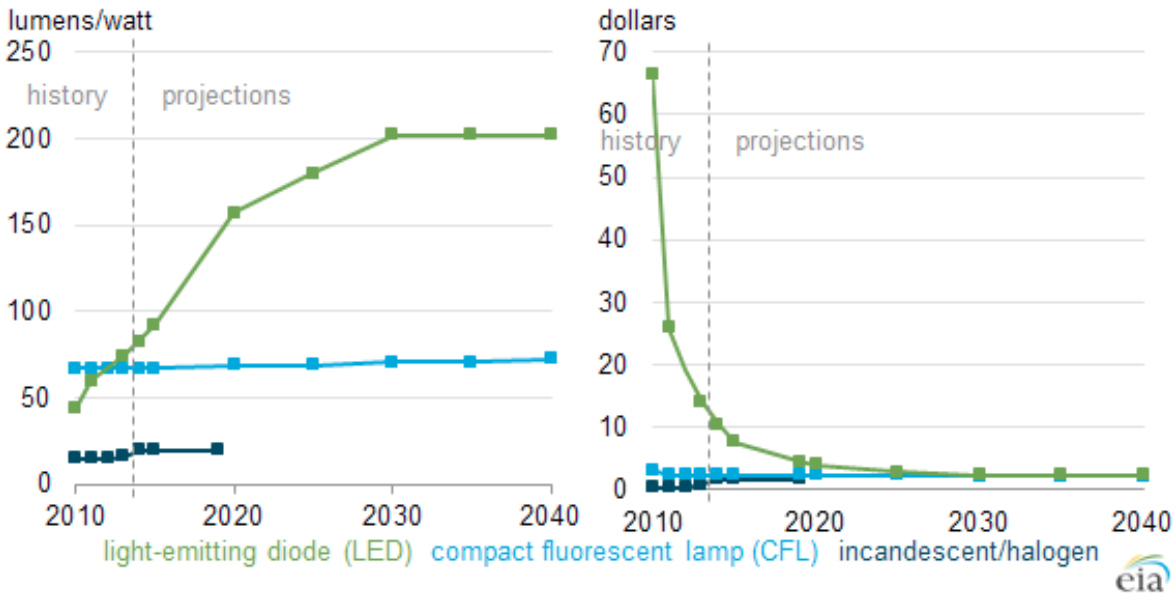


Figure 4, Average lighting efficacy (light output per unit of energy consumed) and cost per bulb. (U.S. Energy Information Administration, 2014)

The cost per LED bulb has been decreasing in the same years from up-to 70 US dollars in 2011 to close-to 10 US dollars in 2015. (Figure. 4) Also looking at the case of solar energy production, for example, the number of solar panels shipped within U.S. in 2009 was 10,511 with the price of 1.95 US dollars per square foot compared to 3,645 solar panels with price of 2.90 US dollars in 1990. Shipments of photovoltaic solar production was 13,837 in 1990 and the number soared to 1,282,560 in 2009 as a result of continuous development which yielded higher efficiency and lower cost. (Statistics Brain Research Institute, 2016)

With big firms now implementing more automation and less environmentally damaging process to help companies cut costs and meet demands with their customers, the small-

to-medium sized companies will be able to benefit from the technologies once they become more available in terms of cheaper cost of installation, after larger companies have integrated the technologies. For example, unlike robotics technology, LED lights have already perforated the wide-ranging consumers market and, as a result, the price of procuring such technology has been reduced significantly in last several years. AS/RS technology has also been around the warehousing industry since 1960s, however with the fast-changing computer and micro-chips development in 1980s, the modern sophisticated system still, especially for SMEs, comes with the hefty price tag. The high attaining cost also applies to solar energy generating solution that the technology is fairly new to reach wide range of purchasers. Nevertheless, like in the case of LED technology, other mentioned solutions will eventually reach fair price.

A survey led by the Aberdeen Group indicates that 37 percent of companies have long-term plan on adopting voice-directed picking system, 33 percent on installing AS/RS solution and 28 percent on investing in sophisticated bar-coding system such as RFID. (Figure. 5)

Technology	% of Companies that Plan to Adopt Within 18 Months	% of Companies That Have Longer-Term Adoption Plans
Bar code scanning	23%	28%
Conveyor-based picking	12%	24%
Cart-based picking	10%	20%
Voice-directed picking	10%	37%
Horizontal carousels	7%	22%
Vertical carousels or VLMs	7%	27%
Pick-to-light	7%	32%
AS/RS	4%	33%

Figure 5. Warehouse Automation Adoption Plan (Aberdeen Group, 2007)

Therefore, significant amount of companies surveyed were interested in investing to certain level in warehousing to improve its operational efficiency.

Therefore, it is safe to conclude the five mentioned solutions will continue to evolve as development continues and both expansion and efficiency will increase as an outcome. Customers and clients will be able to benefit from lowered cost of acquiring technologies and with the high effectiveness of solutions both financial savings and environmental protection will spread across the globe.

5.3 Own learnings

Throughout the thesis development process, I have bolstered my existing knowledge of the fundamentals of warehousing. My study focuses on supply chain management therefore the warehousing was an intrinsic component to be taught. With personal interest in warehousing operation, I was able to widen my expertise of the subject through research and analysis. I have acquired the fundamentals and functions of the warehouse within supply chain operation. I have also garnered how different technological inventions and distinct industries could influence each other by sharing know-hows and eventually increase the efficiency of their operations. Prior to the research I had neither recognition nor appreciation of synergies created within diverse nature of various business industries. Through co-operation and partnership, businesses that seem incomparable at a glance could overcome such dissemblance and achieve outstanding and equivalent competiveness.

5.4 Further development

New technologies are invented and existing ones evolve constantly, even as this paper is being written. As technologies grow quickly and companies seek for better ways to manage supply chain and warehousing, the recurrent need for up-to-date research on new solutions is evident. Because cutting cost and meeting demands from both policy makers and consumers are permanently present, companies restructure the operation and management. Hence, further effort on uncovering newly invented solutions is required.

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Appendices

Appendix 1. Investigative questions (IQs)

1. What are the functions of warehouse and its need for the companies with green supply chain? See chapter 2 and 3
2. What kind of cost-savings and environmental protection be reached by installing DHL's LED lights controlled by the motion detecting sensors? See chapter 4.1
3. What kind of cost-savings and environmental protection be reached by implementing Zetes Industries' RFID and Door Lock system? See chapter 4.2
4. What kind of cost-savings and environmental protection be reached by Amazon robotics' robotic solution? See chapter 4.3
5. What kind of cost-savings and environmental protection be reached by Westfalia's Automatic Storage and Retrieval System (AS/RS) solution? See chapter 4.4
6. What kind of cost-savings and environmental protection be reached by Solgen Energy Group's Warehouse Solar System solution? See chapter 4.5
7. What is the conclusion and demarcation that can be derived from the above research? See chapter 5

Appendix 2. List of acronym

SCM	Supply chain management
GSCM	Green supply chain management
LED	Light-emitting diodes
DHL	Deutsche Post AG
RFID	Radio-frequency Identification
AS/RS	Automated storage and retrieval systems
CROPP	Cooperative/Organic Valley Family of Farms
DC	Direct current
AC	Alternating current
ISO	International Organization for Standardization
CH2	Clifford Hallam Healthcare

Appendix 3. Solar Energy Statistics

Solar Energy Statistics	Data
Average solar panel size needed to power the average home	600 sq. ft.
Average cost of installing a 600 sq. ft. solar system	$52,500
Solar energy share of global energy consumption	0.9 %
Average annual growth rate of global solar energy capacity	102 %
Amount of solar energy that hits the earth each year	8.2 Million Quads
Total quads currently used by the entire globe annually	400 Quads
Percent of earth that would need to be covered with solar panels to power it	0.0005 %
Barrels of oil saved annually by all solar energy users	75 Million Barrels
Tonnes of carbon dioxide saved annually by all solar energy users	35 Million Tonnes

U.S. Solar Energy Production Statistics	2009	2000	1990
Number of U.S. manufactures	13	11	12
Solar panels shipped	10,511	7,948	3,645
Price per square foot	$1.94	$2.09	$2.90
U.S. Photovoltaic Solar Production Statistics			
Number of U.S. manufactures	101	21	19
Shipments	1,282,560	88,221	13,837

(Statistics Brain Research Institute. 2016. Solar Energy Statistics)